

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Acute Trauma to the Knee

Variant 1: Patient any age (excluding infants); fall or twisting injury, no focal tenderness, no effusion; able to walk. First study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	2		☼
MRI knee without contrast	2		O
Tc-99m bone scan with SPECT lower extremity	1		☼☼☼
CT knee without contrast	1	The RRL for the adult procedure is ☼.	☼☼
US knee	1		O
MRA knee with or without contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: Patient any age (excluding infants); fall or twisting injury, with one or more of the following: focal tenderness, effusion, inability to bear weight. First study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9		☼
MRI knee without contrast	5		O
Tc-99m bone scan with SPECT lower extremity	2		☼☼☼
CT knee without contrast	2	The RRL for the adult procedure is ☼.	☼☼
US knee	2		O
MRA knee with or without contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 3: Patient any age (excluding infants); fall or twisting injury with either no fracture or a Second fracture seen on a radiograph, with one or more of the following: focal tenderness, effusion, inability to bear weight. Next study.

Radiologic Procedure	Rating	Comments	RRL*
MRI knee without contrast	9		O
CT knee without contrast	5	The RRL for the adult procedure is ☼.	☼☼
Tc-99m bone scan with SPECT lower extremity	1		☼☼☼
US knee	1		O
MRA knee with or without contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition:**Acute Trauma to the Knee****Variant 4:**

Patient any age (excluding infants); fall or twisting injury with a tibial plateau fracture on a radiograph, with one or more of the following: focal tenderness, effusion, inability to bear weight. Next study.

Radiologic Procedure	Rating	Comments	RRL*
CT knee without contrast	9	May be helpful for treatment planning or prognosis. The RRL for the adult procedure is ☼.	☼☼
MRI knee without contrast	7		O
Tc-99m bone scan with SPECT lower extremity	1		☼☼☼
US knee	1		O
MRA knee with or without contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 5:

Patient any age (excluding infants). Injury to knee 2 days ago, mechanism unknown. Focal patellar tenderness, effusion, able to walk. First study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9		☼
MRI knee without contrast	5		O
Tc-99m bone scan with SPECT lower extremity	2		☼☼☼
CT knee without contrast	2	The RRL for the adult procedure is ☼.	☼☼
US knee	2		O
MRA knee with or without contrast	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 6:

Patient any age (excluding infants). Significant trauma to knee from motor vehicle accident, suspect posterior knee dislocation. First study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9	Initial examination to assess overall injury.	☼
MRI knee without contrast	9	Necessary to evaluate extent of damage to ligament and other support structure.	O
Arteriography lower extremity	7	The RRL for the adult procedure is ☼☼.	☼☼☼
MRA knee with or without contrast	7	Performed in conjunction with MRI of knee.	O
CTA lower extremity with contrast	7	Performed in conjunction with trauma CT imaging. The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
Tc-99m bone scan with SPECT lower extremity	2		☼☼☼
CT knee without contrast	2	The RRL for the adult procedure is ☼.	☼☼
US knee	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

ACUTE TRAUMA TO THE KNEE

Expert Panel on Musculoskeletal Imaging: Michael J. Tuite, MD¹; Richard H. Daffner, MD²; Barbara N. Weissman, MD³; Laura Bancroft, MD⁴; D. Lee Bennett, MD, MA⁵; Judy S. Blebea, MD⁶; Michael A. Bruno, MD⁷; Ian Blair Fries, MD⁸; Curtis W. Hayes, MD⁹; Mark J. Kransdorf, MD¹⁰; Jonathan S. Luchs, MD¹¹; William B. Morrison, MD¹²; Catherine C. Roberts, MD¹³; Stephen C. Scharf, MD¹⁴; David W. Stoller, MD¹⁵; Mihra S. Taljanovic, MD¹⁶; Robert J. Ward, MD¹⁷; James N. Wise, MD¹⁸; Adam C. Zoga, MD.¹⁹

Summary of Literature Review

Introduction/Background

A 2001 report stated that there are 1.3 million annual visits to United States emergency departments because of acute knee trauma, and over \$1 billion are spent on radiographs of the knee [1]. The knee radiograph is the most common radiograph performed for trauma in the emergency room and has the lowest yield for diagnosing clinically significant fractures [2-4]. A retrospective review of 1,967 patients with acute knee injuries revealed that 74.1% of patients had radiographs and only 5.2% had fractures [3]. Fishwick et al [5] concluded that radiographs obtained for acute knee trauma do not reliably depict all important injuries, and that the findings in 25% of knee radiographs obtained for acute trauma do not correlate with the clinical findings.

Radiography

A prospective survey of the judgment and attitudes of experienced clinicians in the use of knee radiography in 1,040 patients with acute knee injuries showed that, despite its inability to accurately predict the probability of fracture and to discriminate between fracture and nonfracture cases, radiographs were usually ordered [2].

The proportion of patients referred for knee radiographs varied from 65.9%-84.6% [3]. According to the physicians, radiographs were ordered for the following reasons: 1) patients expected it and would otherwise be dissatisfied; 2) the physician lacked confidence in the clinical examination, or the orthopedic surgeon considered the radiograph routine; and 3) possible medicolegal repercussions [3]. These reasons and the patients' demand for imaging are recognized as the reasons that implementation of ordering guidelines was not overwhelming [1].

Caution should be used when relying on clinical examination for diagnosing certain knee injuries. Neubauer et al [6] reported that the correct diagnosis of bilateral quadriceps tendon rupture was established in only 61% (17/28) of cases by history and clinical examination alone. Weber et al [4] reported that fractures missed on clinical examination included fractures of the patella, tibial spine, and fibular head.

Clinical decision rules for the acutely injured knee suggest that radiographic examination of the knee following acute injury can be eliminated in most instances by applying specific clinical guidelines [7]. A prospective and retrospective study of 334 patients concluded that patients between 12 and 50 years of age suffering a fall or blunt trauma and unable to ambulate or those who sustained multiple trauma should be radiographed [7]. These authors reported 92% sensitivity and 79% specificity for identifying clinically significant fractures. Their study also reported that applying the clinical decision rules could reduce the number of radiographs taken in the emergency room by 78%.

Weber et al [4] concluded that a clinically significant fracture can be excluded in patients older than 18 years who can walk without limping or if there was a twisting injury to the knee and no joint effusion. If an effusion was present on physical examination, the odds of a fracture were 7.5 times greater. Using this clinical decision rule, the sensitivity for detecting a knee fracture was 100%, and specificity was sufficient to eliminate the need for 29% of knee radiographs ordered in the emergency room.

Stiell et al [2] applied a clinical decision rule (Ottawa Knee Rule) using parameters based on age, palpable tenderness, and function. Under the rule patients with acute knee pain and one or more of the following parameters should have a radiographic examination if they:

- Are 55 years of age or older
- Have palpable tenderness over the head of the fibula
- Have isolated patellar tenderness
- Cannot flex the knee to 90 degrees
- Cannot bear weight immediately following the injury, or

¹Principal Author, University of Wisconsin Hospital, Madison, Wisconsin.

²Panel Chair, Allegheny General Hospital, Pittsburgh, Pennsylvania.

³Panel Vice-chair, Brigham & Women's Hospital, Boston, Massachusetts.

⁴Florida Hospital, Orlando, Florida.

⁵University of Iowa Roy J and Lucille A Carver College of Medicine, Iowa City, Iowa.

⁶Cleveland Clinic, Cleveland, Ohio.

⁷Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania.

⁸Bone, Spine and Hand Surgery, Chartered, Brick, NJ, American Academy of Orthopaedic Surgeons.

⁹VCU Health System, Richmond, Virginia.

¹⁰Mayo Clinic, Jacksonville, Florida.

¹¹Winthrop University Hospital, Mineola, New York.

¹²Thomas Jefferson University Hospital, Philadelphia, Pennsylvania.

¹³Mayo Clinic, Phoenix, Arizona.

¹⁴Lenox Hill Hospital, New Rochelle, New York, Society of Nuclear Medicine.

¹⁵California Pacific Medical Center, San Francisco, California.

¹⁶University of Arizona Health Sciences Center, Tucson, Arizona.

¹⁷Tufts Medical Center, Boston, Massachusetts.

¹⁸University of Kentucky, Lexington, Kentucky.

¹⁹Thomas Jefferson University, Philadelphia, Pennsylvania.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

- Cannot walk in the emergency room (after taking four steps).

This rule was applied prospectively in 1,047 adults with acute knee injuries, and it was determined that its application would result in a 28% relative reduction in the number of radiographs ordered, a decrease from 68.6%-49.4% [2].

A later study [8] was performed to validate the Ottawa Knee Rule [2], and prospective validation analyzing 1,096 patients found it to be 100% sensitive for identifying knee fractures. The decision rule was interpreted correctly 96% of the time, and when applied, the probability of missing a fracture was zero [8]. The decision rule was 100% sensitive for identifying a fracture in patients older than 18 years who were not referred from another hospital, returned for reassessment, had a knee injury for seven days, or had isolated skin lesions. The potential relative reduction in use of radiography was estimated to be 28% (from 74%-53%) [3,8].

In a pooled analysis of data from six studies, Bachmann et al [9] concluded that a negative result using the Ottawa Knee Rule accurately excluded knee fracture after acute knee injury. A meta-analysis to determine the role of radiography in evaluating knee fractures concluded that among the five decision rules evaluated, the Ottawa Knee Rule had the strongest supporting evidence [10]. Further prospective analysis of the Ottawa Knee Rule showed that it allowed a decrease in the number of radiographs performed after knee trauma by 35%, with a sensitivity of knee fracture detection of 100% [11].

Another study [12] compared the implementation of the Ottawa Knee Rule by triage nurses and emergency medicine physicians. No fracture was missed by either group, but triage nurses were found to order 3.6 times more radiographs than emergency physicians, maintaining sensitivity at the expense of specificity and cost savings [12]. Ketelslegers et al [13] evaluated the use of the Ottawa Knee Rule when applied by users with different levels of clinical training, including medical students and surgical residents, and found sensitivity and negative predictive value of 1.0 for both groups and a reduced radiography rate of 25% with application of the rule.

In a study of 214 patients by Verma et al [1] they determined that the use of radiographs in the setting of acute trauma could be further reduced by obtaining a single lateral view. It was reported that the probability of not having a fracture if the lateral view was normal was 100%, thus reducing the need for additional radiographs by 67%.

With regard to mechanism of injury, history and physical examination are key elements for determining the indication for radiographs and the application of a decision rule. The most common mechanisms for knee injury are a direct blow, a fall, or a twisting injury [3-4]. Twisting injuries are responsible for three-fourths of all knee injuries; however, 86% of all knee fractures result from blunt trauma [3-4]. The risk of fracture also

increases with age; fracture is four times more likely in patients older than 50 years, presumably secondary to osteoporosis, increased frequency of blunt injury, and inability to protect the knee during a fall [4].

Absence of immediate swelling, ecchymosis, effusion, deformity, increased warmth, and abrasion/laceration are significant predictors of a normal radiograph. It was generally agreed that radiographs should be obtained and the clinical decision rule should not be applied for patients with gross deformity [4], a palpable mass [8], a penetrating injury, prosthetic hardware, an unreliable clinical history or physical examination secondary to multiple injuries [4,8], altered mental status (eg, head injury, drug or alcohol use, dementia) [4,8], neuropathy (eg, paraplegia, diabetes) [4,8], or a history suggesting increased risk of fracture. The physician's judgment and common sense, however, should supersede clinical guidelines [4].

Transient patellar dislocation is unsuspected clinically in 45-73% of patients with evidence of dislocation subsequently seen on magnetic resonance imaging (MRI) [14-15]. Radiographs may demonstrate a fracture of the medial patella or lateral trochlear, and can also show anatomic features that predispose to dislocation such as a decreased sulcus angle, patella alta, patellar tilt, or patellar subluxation [16]. MRI is more sensitive than radiographs for detecting lateral patellar dislocation, including injury to the medial patellofemoral ligament, bone contusions and osteochondral injuries [17].

Magnetic Resonance Imaging

In addition to clinically significant fractures, other injuries must be considered. Most patients (93.5%) who present with acute knee injuries in the emergency room have soft-tissue rather than osseous injuries [2]. Even in patients with fractures, concomitant soft-tissue injuries frequently are present [18]. Shepherd et al [18] found that in 90% of patients with otherwise nonoperative tibial plateau fractures there were significant soft-tissue injuries diagnosed by MRI, including ligament and meniscal tears. Mustonen et al [19] reported unstable meniscal tears in 36% of patients with tibial plateau fractures. An accurate clinical examination is essential to identify patients at high risk for delayed function recovery due to major soft-tissue injuries. However, using MRI, Frobell et al [20] showed that the first clinical examination after acute knee trauma has a low diagnostic value and that the incidence of anterior cruciate ligament (ACL) injuries is higher than previously described. It is recognized that MRI is the optimal imaging modality for identifying soft-tissue, cartilaginous surface, and bone injuries around the knee.

To image internal knee derangement, MRI has been the technique of choice since the 1990s [21]. The accuracy and reliability of MRI depend on experience and training [22]. Nonetheless, numerous studies have shown that MRI has a high diagnostic accuracy in identifying traumatic intra-articular knee lesions [23-25]. This is particularly true when strict diagnostic criteria are used [23], and this applies to both spin-echo imaging and fast

spin-echo imaging [23] as well as imaging at both low and high field strength [24-25]. MRI has been shown to demonstrate minor meniscocapsular tears when performed with understanding of anatomy [26]. Characteristic findings on MRI, including specific bone marrow edema patterns and osteochondral defects [27], can allow accurate diagnosis of injuries such as transient dislocation of the patella that cannot be detected by radiographs.

MRI is a valuable tool in the decision-making process, altering the treatment plan in 18% of patients with meniscal or chondral surface injuries and allowing earlier surgical intervention because of the more accurate diagnosis obtained [28-30]. Multiple authors and studies have validated that unnecessary diagnostic arthroscopy can be avoided because of the high predictive value of a negative MRI [31-32]. One study [30] found MRI to have a positive predictive value twice that of clinical examination for meniscal tears. It also found that MRI would decrease negative diagnostic arthroscopy to 5% and would help reduce the need for a second therapeutic arthroscopic procedure. Another study [33] reported MRI accuracy to be approximately 94%, showing that it can effectively replace diagnostic arthroscopy for evaluating meniscal and ligament tears. Yet another study [34] reported that when the clinical examination is equivocal within 6 weeks of sudden trauma with a hemarthrosis present, MRI could have prevented diagnostic arthroscopy in 22% of patients. In randomized studies of patients with knee injuries [35-36], MRI findings have been shown to shorten the time to completion of diagnostic workup, reduce the number of additional diagnostic procedures, improve quality of life in the first 6 weeks, and potentially reduce costs associated with lost productivity. MRI should be read with caution in trauma patients without mechanical signs who have osteoarthritis [37].

ACL rupture is responsible for more than 70% of all acute hemarthrosis in young athletes and 17% in a mixed sedentary and athletic population [38-39]. Locking, the presence of a loose body on radiographs, and hemarthrosis within 12 hours of injury have previously been reported as indications for arthroscopy instead of MRI [33,38]. However, McNally et al [40] found that in 48% of patients presenting with an acutely locked knee, management was changed from surgical to conservative based on MRI findings.

Single Photon Emission Computed Tomography

In addition to MRI, single photon emission computed tomography (SPECT) has been proposed for diagnosing meniscus injuries [41-42]. A specific crescentic pattern of uptake on the transaxial view has been described as having a sensitivity of 77% and specificity of 74%. With the additional criterion of increased equilibrium activity in the adjacent femoral condyles, these values increase to 90% and 84%, respectively [41]. Considerable concordance has been shown between SPECT results and those of other modalities for assessing meniscal tears and

the bone contusions from an ACL tear in acute knee trauma [43].

Ultrasound

Sonography has been reported to be 91% sensitive and 100% specific for diagnosing an acute ACL tear within 10 weeks of an acute hemarthrosis when there is no prior trauma and no bone abnormalities [44]. Sonography can be used both for initial detection and confirmation of this injury and for follow-up [45]. Furthermore, a comparison of sonography and radiography using lipohemarthrosis as a criterion of acute intra-articular fracture yielded a sensitivity and specificity of 94% for sonographic detection of such fractures [46]. Wang et al [47] showed that the presence of an effusion at sonography in the acutely injured knee has a 91% positive predictive value for internal derangement. However, intra-articular knee sonography should only be performed and interpreted by personnel with the appropriate expertise in its application.

Computed Tomography

Computed tomography (CT) with three-dimensional reconstruction has been shown to reflect the severity of tibial plateau fractures more accurately than radiography in 43% of cases and to modify the surgical plan in 59% of operative cases [48]. In severely injured patients, diagnostically sufficient radiographs are sometimes difficult to obtain, and therefore a negative radiograph is not reliable in ruling out a fracture [49]. In these patients, multidetector CT is a fast and accurate examination for evaluating tibial plateau fractures and other complex knee injuries [49]. In a 2007 study, Mui et al [50] concluded that in the acute setting, CT offers 80% sensitivity and 98% specificity for depicting osseous avulsions and a high negative predictive value for excluding ligament injury.

Patellar Dislocation

Transient patellar dislocation is unsuspected clinically in 45%-73% of patients with evidence of dislocation subsequently seen on MRI [14-15]. Radiographs may demonstrate a fracture of the medial patella or lateral trochlear, and can also show anatomic features that predispose to dislocation such as a decreased sulcus angle, patella alta, patellar tilt, or patellar subluxation [16]. MRI is more sensitive than radiographs for imaging findings of lateral patellar dislocation, including injury to the medial patellofemoral ligament, bone contusions, and osteochondral injuries [17].

Knee Dislocation

Dislocation of the knee results from a fall from a height, a motor vehicle accident, a vehicle striking a pedestrian, or contact sports [51-52]. This injury, which often reduces spontaneously, constitutes a true orthopedic emergency because of possible nerve or arterial damage. Vascular injury may be found in one-third of patients following posterior knee dislocation [51]. Physical signs of clinically significant vascular injury are the absence of pulses, ischemia, active bleeding, and bruit/thrill. These signs have been reported to have 100% accuracy for

determining the need for surgical exploration [51]. Although one study [53] concluded that angiography is unnecessary in the routine evaluation of patients with blunt lower-extremity trauma who present with a normal neurovascular examination, a systematic review suggested that the isolated presence of abnormal pedal pulses on initial examination following knee dislocation is not sensitive enough to detect a vascular injury that necessitates surgery and that the workup after knee dislocation should include angiography [54]. Computed tomography angiography (CTA) may be used as an alternative to conventional angiography in these patients [55-56].

Yu et al [52] endorsed the use of MRI when evidence of an acute popliteal artery injury is absent, but in the presence of ischemia or lack of pulses to the lower extremity, surgical exploration is suggested. An MRI should also be performed to identify ligamentous injuries and associated pathology [57-59]. Potter et al [60] found excellent correlation between MRI findings and surgical findings in patients with knee dislocation. Furthermore, these authors reported 100% correlation between magnetic resonance angiography (MRA) findings and conventional angiography findings in multiple-ligament injured knees, including knee dislocations [60].

Summary

Clinical decision rules for evaluating the acutely injured knee have been studied by various investigators, who determined that their application can considerably reduce the number of radiographs ordered without missing a clinically significant fracture. Although different parameters and definitions were used for the various decision rules, there were sufficient similarities between the investigations to allow usable conclusions to be drawn.

In patients of any age except for infants, the clinical parameters used for *not requiring* radiographs following knee trauma are as follows:

- Patient is able to walk without a limp [3].
- Patient had a twisting injury, and there is no effusion [3].

The clinical parameters for *ordering* knee radiographs in this population following trauma are as follows:

- Joint effusion within 24 hours of a direct blow or fall [3].
- Palpable tenderness over the fibular head or patella [2].
- Inability to walk (four steps) or bear weight immediately or in the emergency room [2] or within a week of the trauma [1].
- Inability to flex the knee to 90 degrees [2].
- Altered mental status [4,9].

It has also been reported that a fracture can be excluded if a single lateral view of the knee is normal, eliminating the need for additional radiographic views [1].

In general, these studies excluded patients with superficial skin injuries, gross deformity, a palpable mass, a penetrating injury, prosthetic hardware, altered consciousness (from alcohol and/or drug use), multiple injuries, decreased limb sensation, or a history indicating an elevated risk of fracture. They also excluded pregnant patients, patients returning for reassessment, and patients whose injury occurred more than 7 days prior to initial evaluation [3,8].

Soft-tissue injuries (meniscal injuries, chondral surface injuries, and ligamentous disruption) are best evaluated by MRI [21,28-33]. Although lateral patellar dislocation may be reduced at the time of presentation in the emergency room, characteristic findings on MRI, including specific bone marrow edema patterns and osteochondral defects [27], can allow accurate diagnosis.

Knee dislocation, even if spontaneously reduced, constitutes a potential threat to the popliteal nerve or artery. A systematic review [54] has suggested that the isolated presence of abnormal pedal pulses on initial examination following knee dislocation is not sensitive enough to detect a vascular injury that necessitates surgery, and that the workup should include angiography. One study [60] has shown a 100% correlation between MRA findings and conventional angiography findings in multiple-ligament injured knees, including knee dislocations. An MRI should also be performed to identify ligamentous injuries and associated pathology [57-59].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☼	<0.1 mSv	<0.03 mSv
☼☼	0.1-1 mSv	0.03-0.3 mSv
☼☼☼	1-10 mSv	0.3- 3 mSv
☼☼☼☼	10-30 mSv	3-10 mSv
☼☼☼☼☼	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).

Supporting Document(s)

- [ACR Appropriateness Criteria® Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

References

1. Verma A, Su A, Golin AM, O'Marrah B, Amorosa JK. A screening method for knee trauma. *Acad Radiol* 2001; 8(5):392-397.
2. Stiell IG, Greenberg GH, Wells GA, et al. Derivation of a decision rule for the use of radiography in acute knee injuries. *Ann Emerg Med* 1995; 26(4):405-413.
3. Stiell IG, Wells GA, McDowell I, et al. Use of radiography in acute knee injuries: need for clinical decision rules. *Acad Emerg Med* 1995; 2(11):966-973.
4. Weber JE, Jackson RE, Peacock WF, Swor RA, Carley R, Larkin GL. Clinical decision rules discriminate between fractures and nonfractures in acute isolated knee trauma. *Ann Emerg Med* 1995; 26(4):429-433.
5. Fishwick NG, Learmonth DJ, Finlay DB. Knee effusions, radiology and acute knee trauma. *Br J Radiol* 1994; 67(802):934-937.
6. Neubauer T, Wagner M, Potschka T, Riedl M. Bilateral, simultaneous rupture of the quadriceps tendon: a diagnostic pitfall? Report of three cases and meta-analysis of the literature. *Knee Surg Sports Traumatol Arthrosc* 2007; 15(1):43-53.
7. Seaberg DC, Jackson R. Clinical decision rule for knee radiographs. *Am J Emerg Med* 1994; 12(5):541-543.
8. Stiell IG, Greenberg GH, Wells GA, et al. Prospective validation of a decision rule for the use of radiography in acute knee injuries. *JAMA* 1996; 275(8):611-615.
9. Bachmann LM, Haberketh S, Steurer J, ter Riet G. The accuracy of the Ottawa knee rule to rule out knee fractures: a systematic review. *Ann Intern Med* 2004; 140(2):121-124.
10. Jackson JL, O'Malley PG, Kroenke K. Evaluation of acute knee pain in primary care. *Ann Intern Med* 2003; 139(7):575-588.
11. Jenny JY, Boeri C, El Amrani H, et al. Should plain X-rays be routinely performed after blunt knee trauma? A prospective analysis. *J Trauma* 2005; 58(6):1179-1182.
12. Matteucci MJ, Roos JA. Ottawa Knee Rule: a comparison of physician and triage-nurse utilization of a decision rule for knee injury radiography. *J Emerg Med* 2003; 24(2):147-150.
13. Ketelslegers E, Collard X, Vande Berg B, et al. Validation of the Ottawa knee rules in an emergency teaching centre. *Eur Radiol* 2002; 12(5):1218-1220.

14. Kirsch MD, Fitzgerald SW, Friedman H, Rogers LF. Transient lateral patellar dislocation: diagnosis with MR imaging. *AJR* 1993; 161(1):109-113.
15. Lance E, Deutsch AL, Mink JH. Prior lateral patellar dislocation: MR imaging findings. *Radiology* 1993; 189(3):905-907.
16. Colvin AC, West RV. Patellar instability. *J Bone Joint Surg Am* 2008; 90(12):2751-2762.
17. Elias DA, White LM, Fithian DC. Acute lateral patellar dislocation at MR imaging: injury patterns of medial patellar soft-tissue restraints and osteochondral injuries of the inferomedial patella. *Radiology* 2002; 225(3):736-743.
18. Shepherd L, Abdollahi K, Lee J, Vangness CT, Jr. The prevalence of soft tissue injuries in nonoperative tibial plateau fractures as determined by magnetic resonance imaging. *J Orthop Trauma* 2002; 16(9):628-631.
19. Mustonen AO, Koivikko MP, Lindahl J, Koskinen SK. MRI of acute meniscal injury associated with tibial plateau fractures: prevalence, type, and location. *AJR* 2008; 191(4):1002-1009.
20. Frobell RB, Lohmander LS, Roos HP. Acute rotational trauma to the knee: poor agreement between clinical assessment and magnetic resonance imaging findings. *Scand J Med Sci Sports* 2007; 17(2):109-114.
21. Chissell HR, Allum RL, Keightley A. MRI of the knee: its cost-effective use in a district general hospital. *Ann R Coll Surg Engl* 1994; 76(1):26-29.
22. White LM, Schweitzer ME, Deely DM, Morrison WB. The effect of training and experience on the magnetic resonance imaging interpretation of meniscal tears. *Arthroscopy* 1997; 13(2):224-228.
23. De Smet AA, Tuite MJ. Use of the "two-slice-touch" rule for the MRI diagnosis of meniscal tears. *AJR* 2006; 187(4):911-914.
24. Magee T, Williams D. 3.0-T MRI of meniscal tears. *AJR* 2006; 187(2):371-375.
25. Oei EH, Nikken JJ, Verstijnen AC, Ginai AZ, Myriam Hunink MG. MR imaging of the menisci and cruciate ligaments: a systematic review. *Radiology* 2003; 226(3):837-848.
26. George J, Saw KY, Ramlan AA, Packya N, Tan AH, Paul G. Radiological classification of meniscocapsular tears of the anterolateral portion of the lateral meniscus of the knee. *Australas Radiol* 2000; 44(1):19-22.
27. Sanders TG, Paruchuri NB, Zlatkin MB. MRI of osteochondral defects of the lateral femoral condyle: incidence and pattern of injury after transient lateral dislocation of the patella. *AJR* 2006; 187(5):1332-1337.
28. Alioto RJ, Browne JE, Barnhouse CD, Scott AR. The influence of MRI on treatment decisions regarding knee injuries. *Am J Knee Surg* 1999; 12(2):91-97.
29. Mori R, Ochi M, Sakai Y, Adachi N, Uchio Y. Clinical significance of magnetic resonance imaging (MRI) for focal chondral lesions. *Magn Reson Imaging* 1999; 17(8):1135-1140.
30. Munk B, Madsen F, Lundorf E, et al. Clinical magnetic resonance imaging and arthroscopic findings in knees: a comparative prospective study of meniscus anterior cruciate ligament and cartilage lesions. *Arthroscopy* 1998; 14(2):171-175.
31. Suarez-Almazor ME, Kaul P, Kendall CJ, Saunders LD, Johnston DW. The cost-effectiveness of magnetic resonance imaging for patients with internal derangement of the knee. *Int J Technol Assess Health Care* 1999; 15(2):392-405.
32. Elvenes J, Jerome CP, Reikeras O, Johansen O. Magnetic resonance imaging as a screening procedure to avoid arthroscopy for meniscal tears. *Arch Orthop Trauma Surg* 2000; 120(1-2):14-16.
33. Kaplan PA, Dussault RG. Magnetic resonance imaging of the knee: menisci, ligaments, tendons. *Top Magn Reson Imaging* 1993; 5(4):228-248.
34. Munshi M, Davidson M, MacDonald PB, Froese W, Sutherland K. The efficacy of magnetic resonance imaging in acute knee injuries. *Clin J Sport Med* 2000; 10(1):34-39.
35. Nikken JJ, Oei EH, Ginai AZ, et al. Acute peripheral joint injury: cost and effectiveness of low-field-strength MR imaging--results of randomized controlled trial. *Radiology* 2005; 236(3):958-967.
36. Oei EH, Nikken JJ, Ginai AZ, et al. Costs and effectiveness of a brief MRI examination of patients with acute knee injury. *Eur Radiol* 2009; 19(2):409-418.
37. Bhattacharyya T, Gale D, Dewire P, et al. The clinical importance of meniscal tears demonstrated by magnetic resonance imaging in osteoarthritis of the knee. *J Bone Joint Surg Am* 2003; 85-A(1):4-9.

38. Jain AS, Swanson AJ, Murdoch G. Haemarthrosis of the knee joint. *Injury* 1983; 15(3):178-181.
39. Maffulli N, Binfield PM, King JB, Good CJ. Acute haemarthrosis of the knee in athletes. A prospective study of 106 cases. *J Bone Joint Surg Br* 1993; 75(6):945-949.
40. McNally EG, Nasser KN, Dawson S, Goh LA. Role of magnetic resonance imaging in the clinical management of the acutely locked knee. *Skeletal Radiol* 2002; 31(10):570-573.
41. Grevitt MP, Taylor M, Churchill M, Allen P, Ryan PJ, Fogelman I. SPECT imaging in the diagnosis of meniscal tears. *J R Soc Med* 1993; 86(11):639-641.
42. Ryan PJ, Reddy K, Fleetcroft J. A prospective comparison of clinical examination, MRI, bone SPECT, and arthroscopy to detect meniscal tears. *Clin Nucl Med* 1998; 23(12):803-806.
43. Even-Sapir E, Arbel R, Lerman H, Flusser G, Livshitz G, Halperin N. Bone injury associated with anterior cruciate ligament and meniscal tears: assessment with bone single photon emission computed tomography. *Invest Radiol* 2002; 37(9):521-527.
44. Ptasznik R, Feller J, Bartlett J, Fitt G, Mitchell A, Hennessy O. The value of sonography in the diagnosis of traumatic rupture of the anterior cruciate ligament of the knee. *AJR* 1995; 164(6):1461-1463.
45. Gebhard F, Authenrieth M, Strecker W, Kinzl L, Hehl G. Ultrasound evaluation of gravity induced anterior drawer following anterior cruciate ligament lesion. *Knee Surg Sports Traumatol Arthrosc* 1999; 7(3):166-172.
46. Bonnefoy O, Diris B, Moinard M, Aunoble S, Diard F, Hauger O. Acute knee trauma: role of ultrasound. *Eur Radiol* 2006; 16(11):2542-2548.
47. Wang CY, Wang HK, Hsu CY, Shieh JY, Wang TG, Jiang CC. Role of sonographic examination in traumatic knee internal derangement. *Arch Phys Med Rehabil* 2007; 88(8):984-987.
48. Wicky S, Blaser PF, Blanc CH, Leyvraz PF, Schnyder P, Meuli RA. Comparison between standard radiography and spiral CT with 3D reconstruction in the evaluation, classification and management of tibial plateau fractures. *Eur Radiol* 2000; 10(8):1227-1232.
49. Mustonen AO, Koskinen SK, Kiuru MJ. Acute knee trauma: analysis of multidetector computed tomography findings and comparison with conventional radiography. *Acta Radiol* 2005; 46(8):866-874.
50. Mui LW, Engelsohn E, Umans H. Comparison of CT and MRI in patients with tibial plateau fracture: can CT findings predict ligament tear or meniscal injury? *Skeletal Radiol* 2007; 36(2):145-151.
51. Dennis JW, Jagger C, Butcher JL, Menawat SS, Neel M, Frykberg ER. Reassessing the role of arteriograms in the management of posterior knee dislocations. *J Trauma* 1993; 35(5):692-695; discussion 695-697.
52. Yu JS, Goodwin D, Salonen D, et al. Complete dislocation of the knee: spectrum of associated soft-tissue injuries depicted by MR imaging. *AJR* 1995; 164(1):135-139.
53. Abou-Sayed H, Berger DL. Blunt lower-extremity trauma and popliteal artery injuries: revisiting the case for selective arteriography. *Arch Surg* 2002; 137(5):585-589.
54. Barnes CJ, Pietrobon R, Higgins LD. Does the pulse examination in patients with traumatic knee dislocation predict a surgical arterial injury? A meta-analysis. *J Trauma* 2002; 53(6):1109-1114.
55. Fleiter TR, Mervis S. The role of 3D-CTA in the assessment of peripheral vascular lesions in trauma patients. *Eur J Radiol* 2007; 64(1):92-102.
56. Rieger M, Mallouhi A, Tauscher T, Lutz M, Jaschke WR. Traumatic arterial injuries of the extremities: initial evaluation with MDCT angiography. *AJR* 2006; 186(3):656-664.
57. Cole BJ, Harner CD. The multiple ligament injured knee. *Clin Sports Med* 1999; 18(1):241-262.
58. Lonner JH, Dupuy DE, Siliski JM. Comparison of magnetic resonance imaging with operative findings in acute traumatic dislocations of the adult knee. *J Orthop Trauma* 2000; 14(3):183-186.
59. Rubin DA, Kettering JM, Towers JD, Britton CA. MR imaging of knees having isolated and combined ligament injuries. *AJR* 1998; 170(5):1207-1213.
60. Potter HG, Weinstein M, Allen AA, Wickiewicz TL, Helfet DL. Magnetic resonance imaging of the multiple-ligament injured knee. *J Orthop Trauma* 2002; 16(5):330-339.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.